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Efficacy of Botanical Biopesticides against sucking Insect pests of Cauliflower

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ABSTRACT

Sucking insect pests are important constraints to cauliflower production and can adversely affect plant growth and yield when their populations remain uncontrolled. The present study was conducted to evaluate the efficacy of selected botanical biopesticides against major sucking insect pests of cauliflower under field conditions. Four botanical treatments, namely neem powder, neem oil, eucalyptus and datura, were evaluated against whitefly, thrips and aphids, with an untreated control maintained for comparison. Pest populations were recorded before treatment and at 7 and 15 days after each spray, and two applications were made during the crop period. Among the tested treatments, neem powder consistently provided the highest suppression of the major sucking pests. After the first spray, neem powder showed 79.44% efficacy against whitefly, 54.24% against thrips and 81.07% against aphids. Following the second spray, its efficacy increased to 85.54%, 58.95% and 91.43%, respectively. Neem oil ranked second in overall performance, followed by eucalyptus and datura. The untreated control showed the lowest level of pest suppression. Botanical treatments also influenced crop productivity, with the highest cauliflower yield recorded in the neem powder treatment (8,497.14 kg ha^{-1}), followed by neem oil (7,428.57 kg ha^{-1}), eucalyptus (7,142.85 kg ha^{-1}) and datura (5,828.57 kg ha^{-1}), while the untreated control produced 4,857.14 kg ha^{-1}. The findings indicate that neem-based botanicals, particularly neem powder, have considerable potential for suppressing sucking insect pests and improving cauliflower yield and may serve as useful components of integrated pest management programs.

Introduction

Cauliflower (*Brassica oleracea* L. var. *botrytis*) is an important cole vegetable belonging to the family Brassicaceae and is widely cultivated for its edible curd. The crop is valued for its nutritional importance because it contributes several essential nutrients, minerals, vitamins, and other beneficial dietary components to the human diet. In Pakistan, cauliflower is an important vegetable crop and is cultivated in different agro-ecological regions. However, its production is constrained by a number of biotic and abiotic factors, among which insect pests constitute one of the major limitations to obtaining higher and better-quality yields. The original study conducted at Mian Dost Muhammad Agriculture Farm, Rahoki, Tandojam, was undertaken to evaluate botanical biopesticides against sucking insect pests associated with cauliflower.

Cauliflower is attacked by several insect pest species throughout its growing period. The sucking insect pest complex is particularly important because these insects feed directly on plant tissues and plant sap, thereby interfering with normal plant growth and development. In the original study, whitefly, thrips, aphid, and jassid were identified among the insect pests associated with cauliflower. These pests can cause direct damage through feeding and may contribute to weakening of plants, reduction in vigor, and deterioration of crop performance. Sucking pests are particularly important because continuous feeding can reduce plant vigor and may ultimately affect crop productivity. Previous studies have demonstrated the importance of sucking insect pests and the potential of botanical products for their management (Haq, 2006; Hassan et al., 2006; Singh & Kumar, 2003).

Among sucking pests, whiteflies are important because both immature and adult stages remain associated with foliage and obtain nutrients from plant tissues. Their feeding can cause physiological stress to plants and may become particularly damaging when populations increase substantially. Thrips are another important group of pests because of their feeding activity on young and developing plant tissues. Aphids, similarly, can form colonies on plant parts and continuously extract plant sap. Jassids also contribute to the sucking pest complex. The combined occurrence of these insects can increase pest pressure on cauliflower, particularly when favorable environmental conditions support their multiplication and survival. The importance of these pests has been demonstrated in studies evaluating neem-based products against sucking pest complexes in vegetable and cotton crops (Haq, 2006; S. Shahzad Ali et al., 2017; G. Singh et al., 2025).

The management of these pests is essential for maintaining healthy cauliflower plants and obtaining satisfactory yield. Farmers commonly depend on synthetic insecticides because they provide rapid knockdown and are readily available for pest management. However, repeated and indiscriminate application of chemical insecticides may create several problems. These include the development of insecticide resistance, destruction of beneficial organisms, pest resurgence, secondary pest outbreaks, pesticide residues in food, and environmental contamination. The development of insecticide resistance is particularly important because repeated exposure to insecticides can select resistant pest populations and reduce the effectiveness of chemical control programs over time (Shehzad et al., 2023). Therefore, excessive dependence on synthetic insecticides can create both immediate and long-term challenges for sustainable pest management.

The indiscriminate use of chemical pesticides may also disturb the natural balance of agricultural ecosystems. Beneficial insects, including predators and parasitoids, can be adversely affected when broad-spectrum insecticides are repeatedly applied. Such disruption may reduce the contribution of natural enemies to pest regulation and can consequently make pest management more difficult. In addition, repeated exposure of pest populations to the same or similar insecticidal compounds can favor the development of resistance, reducing the effectiveness of chemical control programs over time (Shehzad et al., 2023). These concerns have encouraged researchers to investigate alternative pest-management approaches that can reduce dependence on conventional insecticides.

Integrated pest management (IPM) provides a framework for combining different compatible pest-management methods to maintain pest populations below economically damaging levels. Botanical pesticides can form an important component of such programs because they are derived from plants and contain naturally occurring compounds with biological activity against insects. Plant-derived materials have attracted considerable attention as alternatives or supplements to synthetic insecticides because some possess insecticidal, antifeedant, repellent, and insect growth-regulating properties (G. Singh et al., 2025). Their potential use is particularly relevant in vegetable production, where concerns regarding pesticide residues, environmental contamination, and the conservation of beneficial organisms are important.

Among botanical pesticides, neem (*Azadirachta indica* A. Juss.) has received substantial attention because of its biological activity against a wide range of insect pests. Neem contains several biologically active compounds, among which azadirachtin is considered one of the most important. Neem-derived products may affect insects through several mechanisms, including feeding deterrence, repellency, interference with development, and effects on reproduction (Singh et al., 2025). Previous studies have also reported the efficacy of neem-based products against sucking insect pests of crops such as okra and cotton (Khattak et al., 2006; S. Shahzad Ali et al., 2017; A. Singh & Manish Kumar, 2003).

Neem is particularly attractive for agricultural pest management because different plant parts can be used to prepare botanical products. Neem powder and neem oil are among the preparations commonly evaluated for insect control. The effectiveness of these preparations can vary depending upon the target insect, concentration, method of preparation, application technique, and environmental conditions. Nevertheless, studies have demonstrated that neem-based products can reduce populations of important sucking pests under field conditions. (A. Singh & Manish Kumar, 2003) reported efficacy of neem-based products against cotton jassid on okra, while (Khattak et al., 2006) reported that neem oil and neem seed water extract reduced populations of whiteflies, jassids, and thrips on cotton. These findings indicate that neem-derived products have potential as botanical tools for managing sucking insect pests.

Previous investigations cited in the thesis have reported promising results from neem and other plant-derived materials against sucking insect pests. (A. Singh & Manish Kumar, 2003) reported that neem-based products were effective against cotton jassid, *Amrasca biguttula* Ishida, on okra. (Haq, 2006), in an M.Sc. thesis, investigated different neem products against the sucking pest complex of okra. (S. Shahzad Ali et al., 2017) studied neem plant materials and their effects against sucking insect pests of cotton. Similarly, (Khattak et al., 2006) evaluated neem oil and neem seed water extract against whitefly, jassids, and thrips on cotton. Their results indicated that neem-based treatments could reduce populations of these sucking pests, although the magnitude and duration of control varied according to treatment and pest species.

In addition to neem, other plants have been examined for their insecticidal potential. Eucalyptus and datura are examples of botanicals that may possess biologically active compounds and have been investigated as potential pest-management materials. The use of such locally available plant materials could provide additional options for farmers, particularly where access to commercial biopesticides is limited. (Dutt, 2007) also discussed the use of neem and Datura-based preparations in relation to pest management in cotton. However, these sources should be considered alongside more rigorously documented experimental studies when evaluating the efficacy of botanical treatments.

The effectiveness of botanical pesticides is not necessarily uniform across insect species. Differences in feeding behavior, body structure, developmental stage, and susceptibility to plant-derived compounds may influence treatment performance. In the present study, this aspect was particularly relevant because whitefly, thrips, and aphid populations responded differently to the tested botanical treatments. Neem powder produced the highest efficacy against all three quantitatively assessed sucking pests, but the level of suppression varied among pest groups. Such differences are important when evaluating botanicals for practical pest management because a treatment that performs strongly against one pest may provide only moderate suppression of another. Previous studies of neem products have likewise shown differences in efficacy among sucking pest species and according to the treatment used (Haq, 2006; Khattak et al., 2006; S. Shahzad Ali et al., 2017).

Botanical pesticides may also be valuable from the perspective of sustainable crop production. The use of plant-derived products can reduce exclusive dependence on synthetic insecticides and may provide an additional tool for pest management programs. However, botanical pesticides should not automatically be considered complete substitutes for all conventional pesticides. Their effectiveness depends on proper preparation, concentration, timing, formulation, and application. Therefore, field evaluation is necessary to determine their actual performance under crop production conditions. Differences in the biological activity of neem products and their duration of effectiveness have been demonstrated under field conditions, emphasizing the importance of treatment rate and application timing (Khattak et al., 2006).

The importance of evaluating botanical pesticides is further strengthened by the need to develop pest-management strategies that are compatible with integrated pest management. (Ahuja et al., 2012)) evaluated a farmer-led integrated pest and disease management program in cauliflower and reported a reduction of approximately 50–60% in the number of conventional pesticide sprays. Their study also reported lower insect and disease incidence, higher curd production, and reduced crop-protection costs in IPM fields compared with conventional farmer-practice fields. These findings demonstrate the potential of integrating biorational pesticides, cultural practices, pest monitoring, and other management approaches to reduce reliance on conventional pesticide applications (Ahuja et al., 2012).

The present study was therefore designed to evaluate selected botanical biopesticides against the sucking insect pest complex of cauliflower. Four botanical treatments; neem powder, neem oil, eucalyptus, and datura were compared with an untreated control under field conditions. The study assessed changes in pest populations following application of the treatments and determined their relative efficacy after the first and second sprays. The experiment also evaluated the resulting cauliflower yield so that pest suppression could be considered in relation to crop productivity. The treatments and experimental arrangement were based on the original field experiment conducted at Mian Dost Muhammad Agriculture Farm, Rahoki, Tandojam.

Particular emphasis was placed on determining the relative effectiveness of the botanical treatments against whitefly, thrips, and aphid populations. The original experiment recorded pest populations before treatment and at 7 and 15 days after spraying. This approach permitted assessment of both the immediate and relatively longer-lasting effects of the treatments within the observation period. A second spray was subsequently applied to evaluate whether repeated application could provide further suppression of pest populations.

The study was also important because pest suppression alone does not necessarily demonstrate the agricultural value of a treatment. A successful pest-management treatment should ultimately contribute to maintaining crop growth and productivity. Therefore, cauliflower yield was recorded for each treatment. In the original experiment, neem powder produced the highest yield, followed by neem oil, eucalyptus, and datura, whereas the untreated control produced the lowest yield. These results provide an indication of the potential agricultural value of botanical treatments when pest suppression and crop productivity are considered together.

The overall purpose of this research was thus to assess the potential of selected botanical biopesticides as environmentally compatible tools for the management of sucking insect pests of cauliflower. The study specifically aimed to determine the population of sucking insect pests associated with cauliflower and to identify the most effective plant-derived treatment for their management. The findings are expected to contribute to the development of practical and sustainable pest-management strategies in cauliflower production and to provide a basis for incorporating effective botanical products into integrated pest management programs.

Objectives

1. To determine the major sucking insect pests of cauliflower.
2. To evaluate selected botanical biopesticides against these pests.
3. To compare the efficacy of neem powder, neem oil, eucalyptus and datura.
4. To assess their effect on cauliflower yield.

Materials and Methods

Experimental Site

The field experiment was conducted during 2018 at the experimental area of Mian Dost Muhammad Agriculture Farm, Rahoki, Tandojam. The study was conducted under field conditions to evaluate the effectiveness of selected botanical biopesticides against major sucking insect pests of cauliflower. The crop was grown under the prevailing environmental conditions of the experimental area and maintained using recommended agronomic practices.

Crop and Variety

Cauliflower (*Brassica oleracea* L. var. *botrytis*) was selected as the test crop. The Shahzadi variety was used in the experiment. The crop was established at a row-to-row distance of 60 cm and a plant-to-plant distance of 15 cm. These spacings were maintained throughout the experimental field to provide relatively uniform growing conditions among treatments.

Experimental Design

The experiment was arranged according to a Randomized Complete Block Design (RCBD) with three replications. Five treatments, including four botanical biopesticides and one untreated control, were evaluated. The experimental treatments were randomly allocated within each replication to minimize the influence of field variability on treatment performance. A total of 12 treated plots were described in the experimental layout, with the treatments distributed among the replications.

Treatments

Five treatments were included in the experiment:

Treatment	Botanical biopesticide
T_1	Neem powder
T_2	Neem oil
T_3	Eucalyptus extract
T_4	Datura extract
T_5	Untreated control

The untreated control received no botanical biopesticide application and was maintained for comparison with the treated plots.

Preparation of Botanical Biopesticides

Different plant materials were used for preparation of the botanical treatments. Neem powder was prepared from neem material that was ground using a grinder. Approximately 5 kg of neem material was used for preparation of the aqueous preparation and was soaked for approximately 16 hours. The resulting material was processed to obtain the required preparation for application.

Neem oil was used as a separate botanical treatment. The experimental procedure specified neem oil at a rate equivalent to 1000 ml per acre. A small quantity of surfactant/detergent was incorporated with the preparation to facilitate mixing and application.

For eucalyptus and datura treatments, approximately 5 kg of plant material from each botanical source was chopped into smaller pieces and boiled in approximately 10 L of water. The prepared material was subsequently filtered through muslin cloth to obtain the botanical extract. The filtered preparations were used for spraying the cauliflower crop. The original experimental procedure specified approximately 200 ml of the prepared botanical material per spray tank.

Application of Treatments

The prepared botanical biopesticides were applied to cauliflower plants when sucking insect pests were present in the crop. Two spray applications were conducted during the experiment. Pest populations were recorded immediately before treatment application to establish the pre-treatment population. Following each application, observations were taken at 7 and 15 days after spraying (DAS).

A second spray was applied after the specified interval, and pest populations were again recorded before and after the application. The same observation schedule was followed after the second spray to determine the persistence and comparative effectiveness of the botanical treatments.

Assessment of Sucking Insect Pests

The cauliflower crop was regularly examined for the presence of sucking insect pests. The major pests recorded during the experiment were whitefly, thrips, aphid and jassid. However, quantitative efficacy results presented in the experiment were available for whitefly, thrips and aphid.

Pest populations were recorded before each spray and subsequently at 7 and 15 days after application. The number of insects present on the sampled leaves/plants was recorded for each treatment and replication. These observations were used to determine changes in pest population following application of the different botanical biopesticides.

Whitefly Population Assessment

Whitefly population was assessed before and after application of each botanical treatment. Pre-treatment observations were recorded before spraying, followed by observations at 7 and 15 days after spraying.

The first-spray observations showed that the initial whitefly populations ranged from 4.21 to 4.41 insects per leaf among the botanical treatments and control. After 15 days, populations were reduced to different levels depending upon the treatment. The same procedure was followed after the second spray to determine the additional reduction in whitefly population.

Thrips Population Assessment

Thrips populations were similarly assessed before treatment and at 7 and 15 days after each spray. The number of thrips present on sampled cauliflower leaves was recorded for each treatment.

Following the first spray, pre-treatment populations ranged from 11.19 to 12.43 insects per leaf. After 15 days, the populations differed considerably among treatments, allowing the comparative efficacy of neem powder, neem oil, eucalyptus and datura to be determined. The observations were repeated following the second spray.

Aphid Population Assessment

Aphid populations were recorded using the same observation schedule. The population was recorded before application and at 7 and 15 days after each spray.

Before the first spray, aphid populations ranged from 10.09 to 10.71 insects per leaf across the treatments. After treatment application, the population declined to different levels according to the effectiveness of each botanical preparation. Following the second spray, another set of pre-treatment and post-treatment observations was recorded.

Determination of Pest Reduction

The reduction in pest population was determined by comparing the population recorded before treatment with the population recorded after treatment. The reduction value represented the difference between the pre-treatment pest population and the population observed following application.

The efficacy of each botanical treatment was expressed as a percentage based on the reduction in pest population. This enabled comparison of the relative performance of the four botanical treatments with the untreated control.

Observation Period

Observations were taken at two post-treatment intervals, namely **7 and 15 days after spraying**. Recording observations at both intervals allowed the effectiveness of each botanical treatment to be evaluated over time. The second application provided an opportunity to assess whether repeated treatment resulted in further reduction of pest populations.

Yield Assessment

At harvest, cauliflower yield was recorded for each treatment. The yield obtained from the experimental plots was converted and expressed as **kg ha^{-1}** to facilitate comparison among treatments.

The treatments differed considerably in yield. The highest yield was recorded in the neem powder treatment, followed by neem oil, eucalyptus and datura, whereas the untreated control produced the lowest yield.

Statistical Analysis

The data obtained from the experiment were subjected to statistical analysis using **Statistix 8.1** statistical software. The pest population data recorded before and after application of the treatments were analyzed to determine differences among treatments. Standard error (SE) and least significant difference (LSD) values were used for comparison of treatment means at the specified probability levels.

The statistical analysis allowed the effectiveness of the botanical treatments to be compared objectively and helped determine whether observed differences in pest populations following treatment application were statistically meaningful.

Results

Effect of Botanical Biopesticides on Whitefly Population and Control Efficacy

Before the first spray, whitefly populations did not differ significantly among treatments. After spraying, populations declined over the 7- and 15-day observation periods. At 15 days after the first spray, neem powder reduced the population from 4.33 to 0.89 insects per leaf and produced the highest efficacy (79.44%), followed by neem oil (66.03%), eucalyptus (63.26%) and datura (55.60%). The untreated control showed only 5.69% reduction. After the second spray, neem powder again ranked first, reducing whitefly from 3.32 to 0.48 insects per leaf and producing 85.54% efficacy. Neem oil, eucalyptus and datura produced 68.09%, 57.65% and 44.41% efficacy, respectively, while the untreated control produced 3.20% efficacy.

Table 1. Effect of botanical biopesticides on whitefly after the first spray

Treatment	Pre-treatment	7 days	15 days	Reduction
Neem powder	4.33 ± 0.20	1.04 ± 0.05	0.89 ± 0.04	3.44 ± 0.16
Neem oil	4.21 ± 0.20	1.70 ± 0.08	1.43 ± 0.06	2.78 ± 0.13
Eucalyptus	4.41 ± 0.20	1.93 ± 0.09	1.62 ± 0.08	2.79 ± 0.13
Datura	4.24 ± 0.20	2.93 ± 0.13	1.88 ± 0.09	2.36 ± 0.11
Untreated	4.39 ± 0.20	4.21 ± 0.20	4.14 ± 0.19	0.25 ± 0.01

Values represent means ± SE of three replications.

Table 2. Effect of botanical biopesticides on whitefly after the second spray

Treatment	Pre-treatment	7 days	15 days	Reduction
Neem powder	3.32 ± 0.16	1.01 ± 0.05	0.48 ± 0.02	2.84 ± 0.13
Neem oil	3.04 ± 0.14	1.37 ± 0.06	0.97 ± 0.05	2.07 ± 0.09
Eucalyptus	3.33 ± 0.16	1.86 ± 0.09	1.41 ± 0.06	1.92 ± 0.09
Datura	3.40 ± 0.16	2.22 ± 0.10	1.89 ± 0.09	1.51 ± 0.07
Untreated	3.43 ± 0.16	3.39 ± 0.16	3.32 ± 0.16	0.11 ± 0.00

Values represent means ± SE of three replications.

Effect of Botanical Biopesticides on Thrips Population and Control Efficacy

Thrips populations were also reduced after botanical application. Following the first spray, neem powder produced the highest efficacy (54.24%), followed by neem oil (46.11%), eucalyptus (43.95%) and datura (29.56%); the untreated control showed 3.62% reduction. After the second spray, neem powder again provided the greatest suppression, reducing thrips from 6.87 to 2.82 insects per leaf after 15 days and producing 58.95% efficacy. Neem oil, eucalyptus and datura produced 44.12%, 39.63% and 35.69% efficacy, respectively.

Table 3. Effect of botanical biopesticides on thrips after the first spray

Treatment	Pre-treatment	7 days	15 days	Reduction
Neem powder	11.19 ± 0.52	6.20 ± 0.29	5.12 ± 0.24	6.07 ± 0.28
Neem oil	11.34 ± 0.53	6.39 ± 0.29	6.11 ± 0.28	5.23 ± 0.24
Eucalyptus	11.67 ± 0.54	6.81 ± 0.31	6.54 ± 0.30	5.13 ± 0.24
Datura	11.50 ± 0.53	9.22 ± 0.43	8.10 ± 0.38	3.40 ± 0.16
Untreated	12.43 ± 0.57	12.10 ± 0.56	11.98 ± 0.55	0.45 ± 0.02

Values represent means ± SE of three replications.

Table 4. Effect of botanical biopesticides on thrips after the second spray

Treatment	Pre-treatment	7 days	15 days	Reduction
Neem powder	6.87 ± 0.32	3.41 ± 0.16	2.82 ± 0.13	4.05 ± 0.18
Neem oil	6.64 ± 0.31	4.57 ± 0.21	3.71 ± 0.17	2.93 ± 0.13
Eucalyptus	6.61 ± 0.31	4.81 ± 0.22	3.99 ± 0.18	2.62 ± 0.12
Datura	6.50 ± 0.30	5.22 ± 0.24	4.18 ± 0.19	2.32 ± 0.11
Untreated	8.68 ± 0.40	8.27 ± 0.38	8.11 ± 0.38	0.57 ± 0.02

Values represent means ± SE of three replications.

Effect of Botanical Biopesticides on Aphid Population and Control Efficacy

Aphids showed the strongest response to neem powder. After the first spray, neem powder reduced aphids from 10.09 to 1.91 insects per leaf at 15 days, giving 81.07% efficacy. Neem oil, eucalyptus and datura produced 63.52%, 58.97% and 48.92% efficacy, respectively, while the untreated control produced only 2.62%. After the second spray, neem powder reduced aphids from 7.71 to 0.66 insects per leaf and achieved 91.43% efficacy. Neem oil, eucalyptus and datura produced 67.07%, 62.82% and 59.11% efficacy, respectively.

Table 5. Effect of botanical biopesticides on aphids after the first spray

Treatment	Pre-treatment	7 days	15 days	Reduction
Neem powder	10.09 ± 0.47	2.39 ± 0.11	1.91 ± 0.09	8.18 ± 0.38
Neem oil	10.39 ± 0.48	4.78 ± 0.22	3.79 ± 0.17	6.60 ± 0.31
Eucalyptus	10.58 ± 0.49	6.20 ± 0.29	4.34 ± 0.20	6.24 ± 0.29
Datura	10.71 ± 0.50	5.80 ± 0.27	5.47 ± 0.25	5.24 ± 0.24
Untreated	10.68 ± 0.49	10.78 ± 0.50	10.40 ± 0.48	0.28 ± 0.01

Values represent means ± SE of three replications.

Table 6. Effect of botanical biopesticides on aphids after the second spray

Treatment	Pre-treatment	7 days	15 days	Reduction
Neem powder	7.71 ± 0.36	0.83 ± 0.04	0.66 ± 0.03	7.05 ± 0.33
Neem oil	7.29 ± 0.33	3.01 ± 0.14	2.40 ± 0.11	4.89 ± 0.23
Eucalyptus	7.72 ± 0.36	4.10 ± 0.19	2.87 ± 0.13	4.85 ± 0.23
Datura	7.02 ± 0.32	3.72 ± 0.17	2.87 ± 0.13	4.15 ± 0.19
Untreated	7.42 ± 0.34	7.49 ± 0.35	7.06 ± 0.32	0.36 ± 0.02

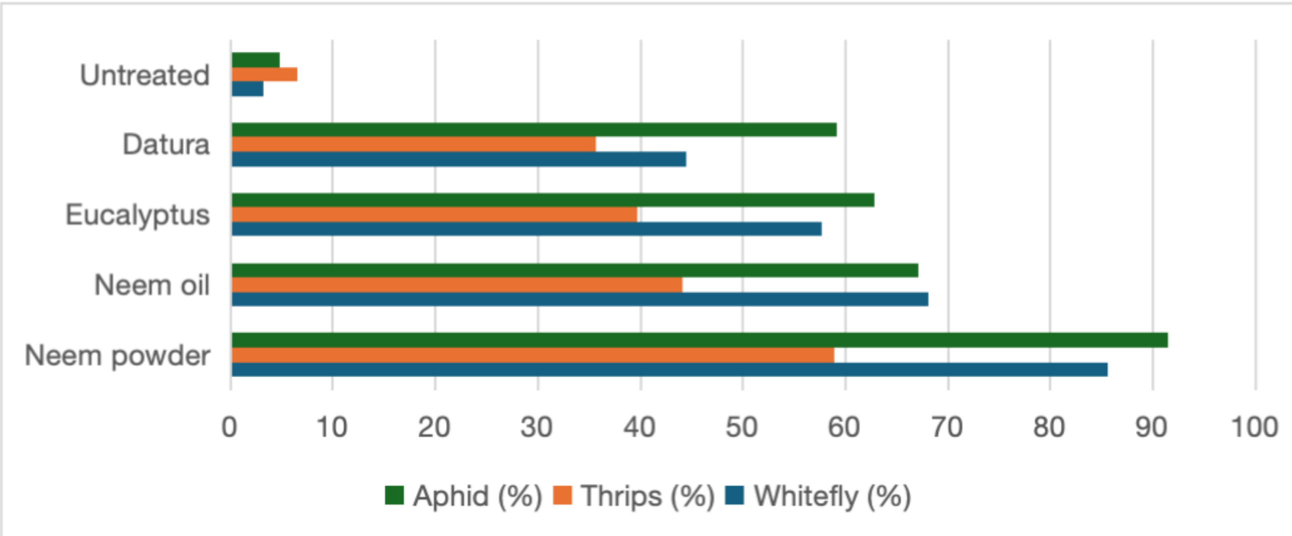
Values represent means ± SE of three replications.

Comparative Efficacy of Botanical Biopesticides Against Major Sucking Insect Pests

The efficacy of the tested botanical biopesticides varied among the major sucking insect pests of cauliflower. Overall, neem powder was the most effective treatment, followed by neem oil, eucalyptus and datura. After the first spray, neem powder showed the highest efficacy against aphids (81.07%), followed by whitefly (79.44%) and thrips (54.24%). Neem oil provided 66.03%, 63.52% and 46.11% efficacy against whitefly, aphid and thrips, respectively. Eucalyptus showed moderate efficacy, with 63.26% control of whitefly, 58.97% of aphid and 43.95% of thrips. Datura was comparatively less effective, recording 55.60%, 48.92% and 29.56% efficacy against whitefly, aphid and thrips, respectively. The untreated control showed only a small reduction in pest populations.

Following the second spray, the effectiveness of the botanical treatments generally increased. Neem powder again demonstrated the highest overall efficacy, recording 91.43% against aphids, 85.54% against whitefly and 58.95% against thrips. Neem oil ranked second, with efficacy values of 68.09% against whitefly, 67.07% against aphid and 44.12% against thrips. Eucalyptus provided 62.82% control of aphids, 57.65% control of whitefly and 39.63% control of thrips. Datura showed comparatively lower efficacy against whitefly (44.41%), while its efficacy against thrips and aphids was 35.69% and 59.11%, respectively. These results indicate that the response of the pests differed among botanical treatments, with aphids and whiteflies generally showing greater susceptibility to neem-based treatments than thrips.

Figure 1. Comparative Efficacy of Botanical Biopesticides Against Major Sucking Insect Pests of Cauliflower.



Effect of Botanical Biopesticides on Cauliflower Yield

Botanical treatments were associated with higher cauliflower yield than the untreated control. Neem powder produced the highest yield (8497.14 kg ha^{-1}), followed by neem oil (7428.57 kg ha^{-1}), eucalyptus (7142.85 kg ha^{-1}) and datura (5828.57 kg ha^{-1}). The untreated control produced the lowest yield (4857.14 kg ha^{-1}).

Table 7. Cauliflower yield under different botanical treatments

Treatment	Yield (kg ha^{-1})
Neem powder	8,497.14
Neem oil	7,428.57

Eucalyptus	7,142.85
Datura	5,828.57
Untreated	4,857.14

Figure 2. Efficacy of botanical biopesticides against major sucking pests after the first spray

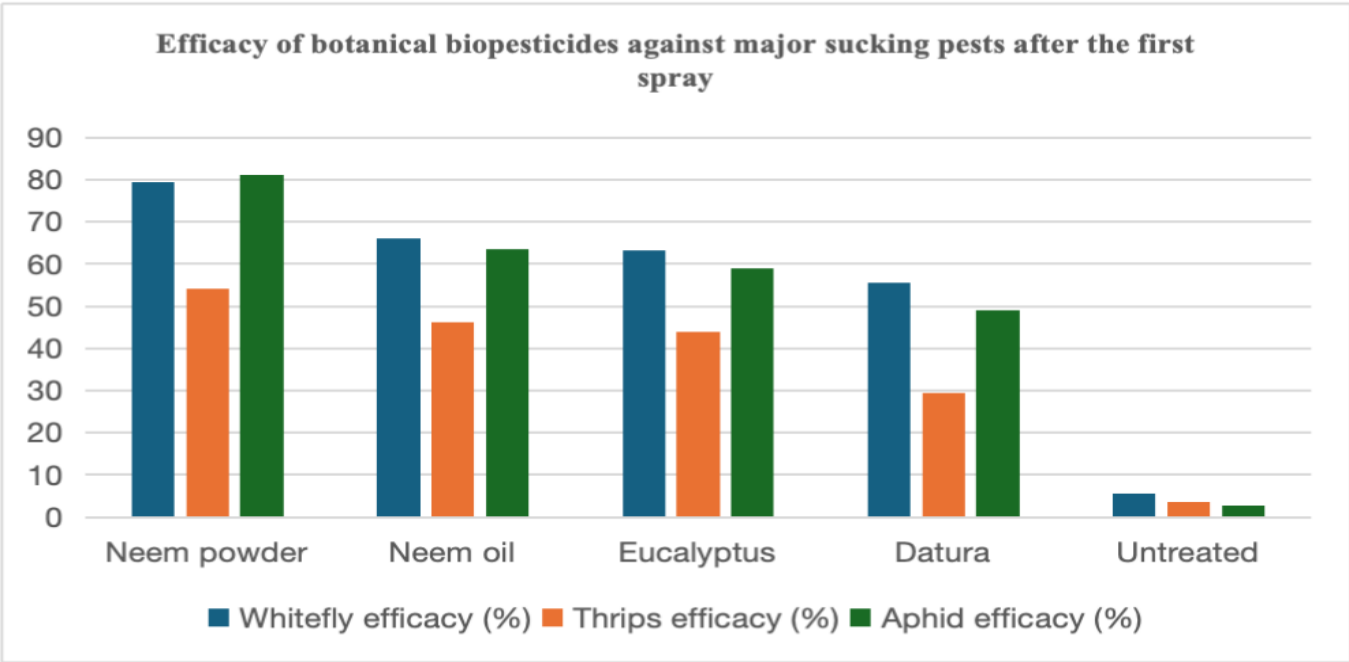
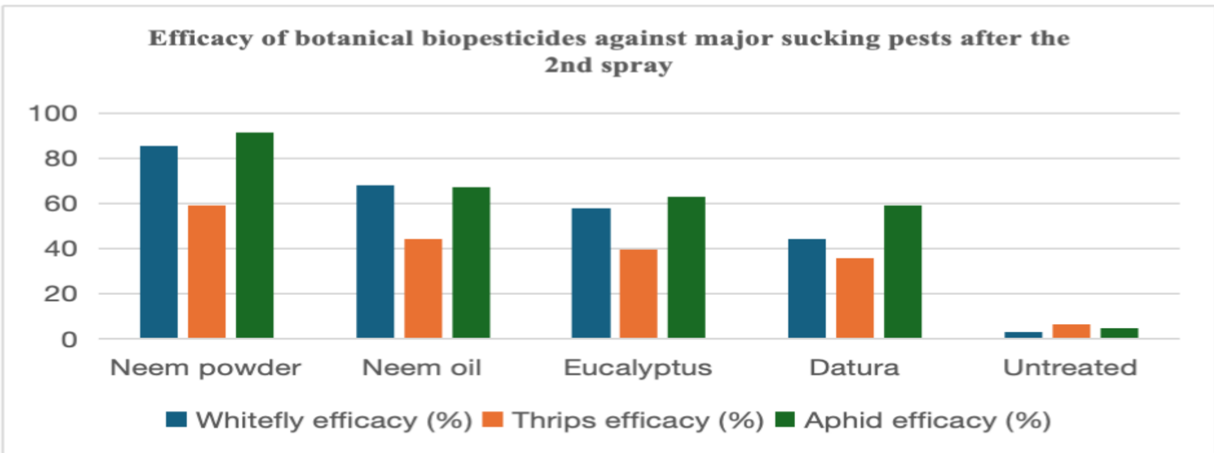


Figure 3. Efficacy of botanical biopesticides against major sucking pests after the 2nd spray

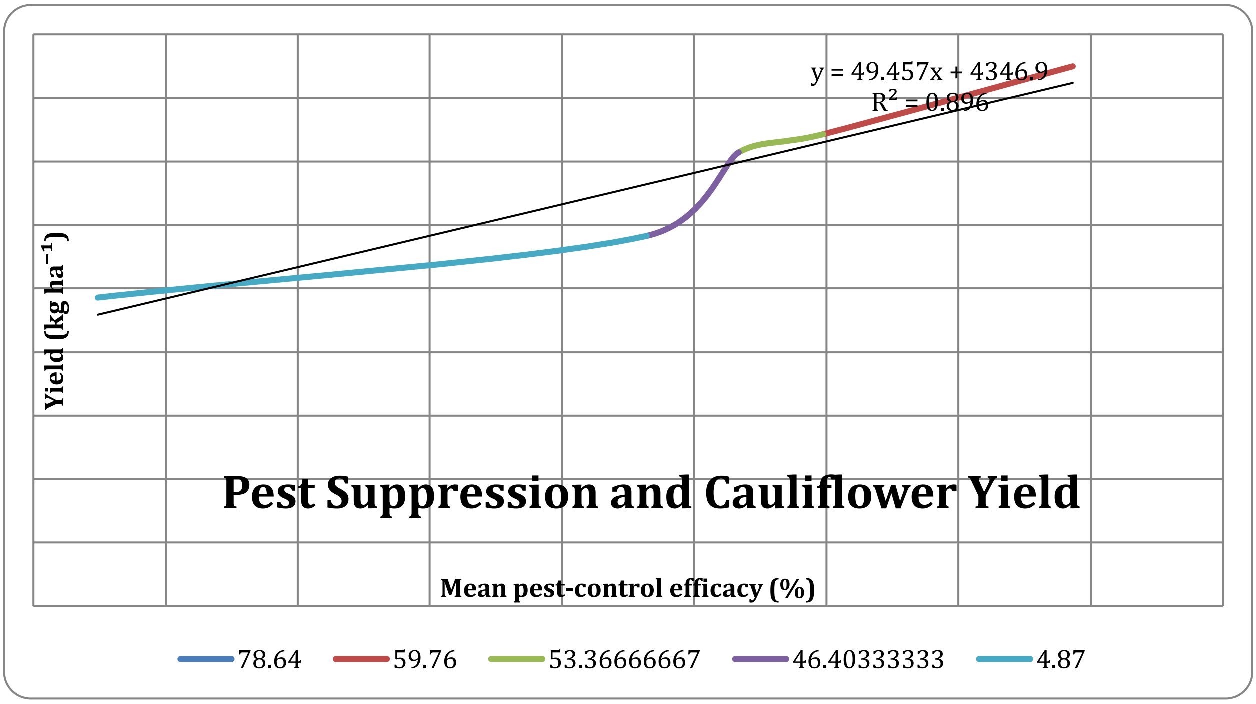


Relationship Between Pest Suppression and Cauliflower Yield

The results showed a clear treatment-wise pattern between suppression of sucking insect pests and cauliflower yield. Treatments that provided greater pest suppression generally recorded higher yields than the untreated control. Neem powder, which produced the highest efficacy against whitefly, thrips and aphids, also resulted in the highest cauliflower yield of 8497.14 kg ha^{-1}. Neem oil ranked second with a yield of 7428.57 kg ha^{-1}**,** followed by eucalyptus with 7142.85 kg ha^{-1} and datura with 5828.57 kg ha^{-1}**.** The untreated control recorded the lowest yield of 4857.14 kg ha^{-1}**.**

The higher yield recorded in the botanical treatments may be associated with the reduction in sucking pest populations observed after application. Neem powder provided the greatest suppression of the major sucking pests and consequently produced the highest yield, whereas the untreated control had the lowest pest-management performance and the lowest yield. The difference between neem powder and the untreated control was substantial, with neem powder producing approximately 75% higher yield than the untreated treatment. Overall, the results indicate that effective suppression of sucking insect pests was associated with improved cauliflower productivity under the conditions of the experiment.

Figure 4: Relationship Between Pest Suppression and Cauliflower Yield



Discussion

The present study demonstrated that botanical biopesticides can provide effective suppression of major sucking insect pests associated with cauliflower. Neem powder, neem oil, eucalyptus and datura were evaluated under field conditions against whitefly, thrips and aphids, with an untreated control included for comparison. The treatments differed in their ability to reduce pest populations, and neem powder consistently produced the highest level of suppression. The overall response was more pronounced after the second spray, indicating that repeated application of effective botanical treatments can improve pest suppression over the crop-growing period. The results are in agreement with the general potential of neem-based products as botanical pest-management tools reported in previous studies. (Lowery & Isman, 1994), for example, demonstrated strong insect growth-regulating effects of neem extracts and azadirachtin against aphids.

The results obtained against whitefly showed that neem powder was the most effective treatment after both sprays. Following the first spray, neem powder resulted in 79.44% efficacy, followed by neem oil (66.03%), eucalyptus (63.26%) and datura (55.60%). After the second spray, efficacy of neem powder increased to 85.54%, while neem oil and eucalyptus produced 68.09% and 57.65% efficacy, respectively. Datura showed comparatively lower effectiveness. The higher suppression obtained with neem powder may be related to the insecticidal, antifeedant and growth-regulating properties of neem-derived compounds. Khattak et al. (2006) similarly reported that neem oil and neem seed water extract significantly reduced whitefly populations along with jassids and thrips under field conditions. Their findings also indicated that neem treatments maintained measurable activity for several days following application.

The relatively strong response of whitefly to neem treatments in the present study is also consistent with observations from other field studies involving botanical pesticides. (B & P, 2012) reported that fermented neem leaf extracts reduced whitefly and aphid populations compared with untreated plants, and that combinations of neem and wild garlic extracts could provide greater suppression than individual extracts. These findings support the present observation that neem-based preparations can be useful against sap-feeding pests and may provide sustained population suppression when incorporated into a field pest-management program.

The response of thrips was comparatively lower than that of whitefly and aphids. After the first spray, neem powder produced 54.24% efficacy, followed by neem oil (46.11%), eucalyptus (43.95%) and datura (29.56%). Following the second spray, neem powder again ranked first with 58.95% efficacy, whereas neem oil, eucalyptus and datura produced 44.12%, 39.63% and 35.69% efficacy, respectively. The lower efficacy against thrips suggests that this pest may be comparatively less susceptible to the tested botanical preparations under the conditions of the experiment. Differences in feeding behavior, distribution on plant tissues, developmental stages and exposure to plant-derived compounds may contribute to variation in response among pest species. Khattak et al. (2006) reported significant reductions in thrips populations following application of neem oil and neem seed water extract, supporting the potential of neem-based treatments for management of thrips and other sucking pests.

Aphids showed the greatest response to the botanical treatments, particularly neem powder. After the first spray, neem powder recorded 81.07% efficacy, followed by neem oil (63.52%), eucalyptus (58.97%) and datura (48.92%). After the second spray, efficacy of neem powder increased to 91.43%, while neem oil, eucalyptus and datura produced 67.07%, 62.82% and 59.11%, respectively. The high level of aphid suppression observed with neem powder is consistent with the findings of (Lowery & Isman, 1994), who reported strong growth-regulating effects of neem extracts and azadirachtin against aphids. Their study demonstrated substantial mortality of aphid nymphs following exposure to neem seed oil, supporting the biological activity of neem-derived materials against aphid populations.

The present findings are also comparable with the work of (A. Singh & Manish Kumar, 2003), who evaluated neem-based products against cotton jassid and reported useful pest-management activity. (Haq, 2006) similarly reported that different neem products were effective against the sucking pest complex of okra, including whitefly, thrips, aphids and jassids. Hassan et al. (2006) also reported useful activity of neem plant materials against sucking insect pests of cotton. These observations collectively indicate that neem-derived preparations have potential against a broad range of sap-feeding insects rather than being effective against only one particular pest species. The available literature therefore provides support for the consistent ranking of neem powder as the most effective botanical treatment in the present experiment.

The comparative performance of the four botanical treatments indicated that neem powder was consistently superior, followed by neem oil, eucalyptus and datura. This ranking was evident across whitefly, thrips and aphid populations. The greater effectiveness of neem powder may be associated with the concentration and availability of bioactive constituents in the applied material. Neem contains several biologically active compounds that can influence insect feeding, growth, development and reproduction. The effectiveness of neem-based products has also been attributed to their antifeedant and deterrent effects, which can contribute to reduction in pest activity following application. Khattak et al. (2006) suggested that reductions following neem treatment may be associated with antifeedant and deterrent effects of neem compounds.

The improvement in pest suppression following the second spray was another important finding of the study. Whitefly efficacy with neem powder increased from 79.44% after the first spray to 85.54% after the second spray, while aphid efficacy increased from 81.07% to 91.43%. Thrips efficacy also increased from 54.24% to 58.95%. This pattern suggests that repeated application of effective botanical treatments can enhance suppression and maintain pest populations at comparatively lower levels. The original experiment recorded pest populations before spraying and at 7 and 15 days after treatment, allowing the persistence of treatment effects to be assessed over the observation period.

The results obtained in the present study are consistent with the broader literature on botanical pesticides. (Debashri & Mondal, 2012) reviewed the use of Azadirachta indica-based biopesticides and highlighted the wide range of insect pests affected by neem-derived products. They also emphasized the biodegradability and relatively low persistence of neem-based pesticides, which contribute to their potential value in sustainable pest-management programs. The present results provide field-level support for this potential because neem powder and neem oil were able to reduce important sucking pest populations without relying solely on conventional synthetic insecticides.

The performance of eucalyptus and datura was moderate compared with the neem treatments. Although both treatments reduced pest populations relative to the untreated control, their efficacy was generally lower and less consistent than that of neem powder. Datura produced 55.60% efficacy against whitefly after the first spray and 29.56% against thrips, whereas its efficacy against aphids was 48.92%. Following the second spray, datura produced 44.41%, 35.69% and 59.11% efficacy against whitefly, thrips and aphids, respectively. These results indicate that plant extracts should not be assumed to have equal insecticidal potential. Differences in phytochemical composition, extraction or preparation method, concentration, pest species and environmental conditions can influence their field performance.

The yield results further demonstrated the agricultural importance of pest suppression. Neem powder produced the highest cauliflower yield of 8,497.14 kg ha^{-1}, followed by neem oil with 7,428.57 kg ha^{-1}, eucalyptus with 7,142.85 kg ha^{-1} and datura with 5,828.57 kg ha^{-1}. The untreated control produced the lowest yield of 4,857.14 kg ha^{-1}. Thus, the treatment providing the highest overall pest suppression also produced the highest crop yield. This pattern suggests that reduction in sucking pest pressure was associated with improved crop productivity under the conditions of the experiment. The original experimental results similarly showed the highest yield under neem powder and the lowest yield in the untreated treatment.

The higher yield obtained from neem-treated plants may be explained by the reduction in pest feeding pressure during crop development. Sucking pests continuously remove plant sap and can reduce plant vigor when populations become sufficiently high. Consequently, effective suppression of these pests can help maintain plant growth and improve the crop's capacity to produce marketable curds. (RAHMAN, 2018) similarly reported that neem seed extract was associated with lower aphid infestation and higher crop yield. The present results therefore suggest that the benefits of botanical treatments extended beyond direct pest reduction and were reflected in improved crop production.

The results also have relevance to integrated pest management. (Ahuja et al., 2012) reported that implementation of an integrated pest and disease management program in irrigated cauliflower reduced conventional pesticide sprays by 50–60% while maintaining lower pest and disease incidence and higher curd production. Their findings demonstrate that safer biorational pesticides and cultural practices can be incorporated into broader management programs rather than relying exclusively on conventional insecticides. The present study similarly indicates that botanical treatments, particularly neem-based preparations, could serve as components of an IPM strategy for managing sucking pests in cauliflower.

The findings should nevertheless be interpreted within the conditions of the experiment. Botanical pesticide performance can be affected by environmental conditions, pest density, plant age, formulation, concentration, application method and persistence of active compounds. In addition, botanical treatments generally act differently from fast-acting synthetic insecticides and may require repeated applications to maintain effective pest suppression. Therefore, neem powder or neem oil should preferably be considered as components of an integrated management program rather than as complete replacements for every other pest-management measure.

Overall, the present study demonstrated that botanical biopesticides differed substantially in their effectiveness against sucking insect pests of cauliflower. Neem powder consistently produced the highest efficacy against whitefly, thrips and aphids and also resulted in the highest cauliflower yield. Neem oil was the second most effective treatment, while eucalyptus and datura provided moderate suppression. The improvement in efficacy following the second spray further suggests that repeated application can enhance pest suppression. These findings are generally consistent with previous research demonstrating the potential of neem-derived products against sucking insect pests. The results support the incorporation of neem-based botanical treatments into integrated pest management programs for cauliflower, particularly where the objective is to reduce dependence on repeated applications of conventional synthetic insecticides.

Conclusion

The present study demonstrated that botanical biopesticides have considerable potential for the management of major sucking insect pests of cauliflower. Among the tested treatments, neem powder was the most effective botanical treatment and consistently provided the highest suppression of whitefly, thrips and aphids after both spray applications. Its efficacy increased following the second spray, indicating improved pest suppression with repeated application. Neem oil ranked second in overall effectiveness, followed by eucalyptus and datura, while the untreated control showed the lowest level of pest suppression.

The use of botanical treatments also had a positive effect on cauliflower productivity. The highest yield was recorded in the neem powder treatment (8,497.14 kg ha^{-1}), followed by neem oil (7,428.57 kg ha^{-1}), eucalyptus (7,142.85 kg ha^{-1}) and datura (5,828.57 kg ha^{-1}). The untreated control produced the lowest yield (4,857.14 kg ha^{-1}). The higher yield associated with neem powder corresponded with its greater ability to suppress the sucking pest complex. Overall, the results indicate that neem powder, particularly, can be considered an effective botanical option for reducing sucking insect pest populations and improving cauliflower production. Botanical biopesticides therefore have potential for incorporation into integrated pest management programs as safer and more environmentally compatible pest-management tools.

Recommendations

- Neem powder should be considered as a preferred botanical treatment for the management of major sucking insect pests of cauliflower because it provided the highest overall pest suppression and crop yield.
- Neem oil may be used as an alternative neem-based treatment where neem powder is not readily available or where an oil-based formulation is more suitable for application.
- Botanical biopesticides should be incorporated into integrated pest management programs rather than relying exclusively on repeated applications of synthetic insecticides.
- Repeated application of effective botanical treatments may be considered where pest populations persist, as the second spray provided greater suppression than the first spray in the present study.

- Regular field scouting should be conducted to identify whitefly, thrips and aphid populations at an early stage and to determine the appropriate timing of botanical applications.
- Farmers should follow recommended application rates and proper spray techniques to ensure adequate coverage of cauliflower foliage and improve treatment effectiveness.

Suggestions For Future Research

1. Further field experiments should be conducted at different locations and during different growing seasons to validate the effectiveness of neem powder and other botanical treatments under varying environmental conditions.
2. Different concentrations of neem powder, neem oil, eucalyptus and datura should be evaluated to determine the most effective and economical application rates.
3. Future studies should evaluate combinations of different botanical extracts to determine whether their combined application can provide greater or more persistent suppression of sucking insect pests.
4. The residual activity of botanical treatments should be investigated at shorter and longer intervals after application to determine their persistence under field conditions.
5. Further research should examine the effects of botanical biopesticides on beneficial insects, including predators and parasitoids, to assess their compatibility with biological control agents.
6. Additional studies should investigate the economic benefits of botanical pest management by comparing treatment costs, pest suppression, crop yield and net returns.
7. Future experiments should include detailed observations on all major sucking insect pests, including jassids, together with whitefly, thrips and aphids, to provide a more comprehensive assessment of the pest complex.
8. Long-term studies should be conducted to evaluate the potential of botanical biopesticides as sustainable alternatives to frequent synthetic insecticide applications in cauliflower production.

Author Contributions

All authors contributed equally in the manuscript.

Competing Of Interest

The authors declare no competing interests.

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